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CERTIFICATION OF ATTACHED ENGLISH TRANSLATION OF PCT APPLICATION:

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I hereby certify the English translation attached is a true and accurate copy of the referenced PCT/EP2004/006256 application.

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REFRIGERATION DEVICE COMPRISING CONTROLLED DE-HUMIDIFICATION

The present invention relates to a no-frost refrigeration device and an operating method for such a device.

In refrigeration devices of this type, an evaporator is disposed in a chamber separated from a storage compartment for chilled goods and heat exchange takes place between the chamber and the storage compartment by which means the storage compartment is cooled by blowing cooled and dried air into the storage compartment with the aid of a fan at the evaporator and extracting relatively warm moist air from the storage compartment into the chamber. In this case, the storage compartment is not only cooled but also de-humidified. The moisture is deposited on the evaporator. This de-humidification prevents condensation from being deposited on storage surfaces and chilled goods in the storage compartment under critical climatic conditions, especially when the refrigerator is used in a warm environment at high air humidity. However, under less critical ambient conditions, this advantage can be converted into a disadvantage if stored foodstuffs are dried out by the intensive de-humidification.

There is thus a need for a no-frost refrigeration device and an operating method for such a device which allows flexible adaptation to the climatic conditions in the environment of the refrigerator.

The object was solved by a refrigeration device having the features of claim 1 or a method having the features of claim 10.

By varying the circulation power of the fan in such a refrigeration device, at a given temperature difference between the storage compartment of the refrigeration device and the evaporator the heat flow between the two is also varied. That is

to say, a reduction in the circulation power results in a reduced heat exchange and thus in stronger cooling of the evaporator. This intensified cooling causes more intensive drying of the air flowing past the evaporator. At the same time, the reduced circulation power has the effect that if the evaporator and fan are both activated, the cooling of the storage compartment takes place more slowly than at a higher circulation power so that the activation time of the evaporator is lengthened. This lengthening compensates for the reduced circulation power and has the result that in the course of an activation phase of the evaporator, more moisture is collected at low circulation power that at high circulation power.

A variable circulation power of the evaporator can be simply achieved by making the fan capable of being deactivated temporarily in the activated phase of the evaporator. Advantageously, a control circuit is provided for controlling the operation of the evaporator and the fan which is set up to intermittently operate the fan when the evaporator is activated and thereby throttle its average circulation power compared to continuous operation.

A selector switch can be provided on the refrigeration device which allows the user to set a duty cycle for the intermittent operation of the fan and thus adapt the drying effect of the refrigeration device to the requirement. In a more convenient embodiment the control circuit is coupled to at least one air conditioning sensor to record an air conditioning parameter such as the ambient temperature of the refrigeration device, the humidity of the ambient air or the humidity of the air in the interior and is set up to control the duty cycle as a function of at least one air conditioning parameter recorded by the sensor.

As a result of another embodiment in the activation phase of the evaporator, the fan can be set to different non-zero speeds to adapt the average circulation power to the requirements. Here also a selector switch can be provided which allows the user to preset a desired speed for the control circuit of the fan or the control circuit can be coupled to at least one air conditioning sensor in order to automatically control the circulation power of the fan using an air-conditioning parameter recorded by the sensor and a predefined target value of the air humidity.

The subject matter of the invention is also a method for operating a refrigeration device of the type described above, comprising the steps:

a) estimating a moisture value in the storage compartment of the refrigeration device;
b) selecting a circulating power for the fan as a function of the estimated moisture value;
c) operating the fan at the selected circulating power.

The estimate preferably comprises an air humidity measurement made directly in the affected storage compartment. It is then especially possible to take into account influences of the operation of the evaporator and the fan on the air humidity in the storage compartment when selecting the circulation power. In principle, however, it is also possible to estimate the air humidity in the storage compartment by using quantities correlated therewith such as temperature and air humidity of the environment and to select the circulation power as a function of the result of the estimate.

Further features and advantages of the invention are obtained from the following description of the exemplary embodiments with reference to the appended figures. In the figures:

Figure 1 is a schematic diagram of a no-frost refrigeration device according to the invention,

Figure 2 is a time diagram of the operation of an evaporator and fan according to a first embodiment of the invention; and

Figure 3 is a time diagram similar to Figure 2 for a second embodiment of the invention.

Figure 1 is a schematic diagram of a combination refrigeration device on which the present invention is implemented. A cooling compartment 1 and a freezing compartment 2 form two temperature zones of the refrigeration device. A coolant circuit comprises a compressor 3 which pumps a compressed coolant successively through two evaporators 4, 5 of the freezing compartment 2 or the cooling compartment 1 and a heat exchanger 6 through which the coolant passes after it has expanded in the evaporators 4, 5 before it re-enters the compressor 3. The evaporator 5 associated with the cooling compartment 1 is accommodated in a chamber 8 separated from the cooling compartment 1 by a thermally insulating wall 7. The chamber 8 communicates with the cooling compartment 1 via air inlet and outlet openings and a fan 9 for forced circulation of air between the chamber 8 and the cooling compartment 1 is disposed in one of said openings.

A control circuit 10 is connected to a temperature sensor 12 arranged in the cooling compartment and via control leads to the compressor 3 and the fan 9 and is capable of activating or de-activating the compressor 3 and the fan 9, and indirectly via the compressor 3 the evaporators 4, 5, depending on a temperature recorded by the temperature sensor 12. The control circuit 10 is further connected to an air humidity sensor 13 which is disposed in the cooling compartment 1. A user-actuated selector switch 11 can be provided at the control circuit 10 which can be used to select a target value for the air humidity in the cooling compartment 1.

As a variant, the air humidity sensor 13 in the cooling compartment 1 can also be replaced by an air humidity sensor outside the cooling compartment and/or a sensor for the ambient temperature of the refrigeration device since its measured values allow the air humidity in the cooling compartment 1 to be deduced.

Figure 2 illustrates the operating mode of the control circuit 10 with reference to the time profiles of a plurality of operating parameters of the refrigeration device. Curve 3' gives the operating state of the compressor 3. At time t_0 it is de-activated; as soon as the temperature sensor 12 records that an upper limiting temperature has been exceeded, at time t_1 it is activated until at time t_2 the temperature in the cooling compartment 1 falls below a lower limit. From this time the cooling compartment 1 heats up again until at time t_3 a new activation phase of the compressor 3 begins.

From t_0 to t_1 the air humidity recorded by the sensor 13 in the cooling compartment 1 is at a constant low level. When the compressor 3 is activated, at time t_1 the fan 9 also starts operating, as shown by a curve 9'. The temperature of the evaporator 5, shown by curve 5', returns from a rest value T_0 to a value T_1. Moisture from the air circulated by the fan 9 is deposited on the evaporator 5 so that the air humidity 13' decreases slowly as far as the time t_2 when the fan 9 is de-activated. From the time t_3 the humidity 13' increases substantially, for example, because the door of the refrigeration device is opened and warm moist air penetrates from outside. The control circuit 10 recognises that more intensive drying is required and operates the fan 9 when at time t_4 the compressor 3 is activated again, intermittently with a duty cycle which is selected as a function of the air humidity recorded at time t_4. This results in an average lower circulation

power of the fan 9 than that during the time interval t_1 to t_2 so that heat exchange between the evaporator 5 and the cooling compartment 1 is slowed. The activation time interval t_4 to t_5 is thus longer than the time interval t_1 to t_2 and the temperature T_2 of the evaporator 5 achieved during this time interval is lower than T_1. This lower temperature T_2 has the result that the air flowing past the evaporator 5 is dried more effectively and as a result of the lengthened activation time of the compressor 3, a low air humidity value is finally achieved again.

The duty cycle with which the control circuit 10 operates the fan during the activation phase of the evaporator is, in the simplest case, a step function which has the value 1 for low air humidities and a non-zero value less than 1 for high air humidities; a step function having a plurality of values of the duty cycle which decrease with increasing air humidity or a continuous function can also be used for the control.

In a second embodiment of the invention the control circuit 10 is designed to set different speeds of the fan 9 as a function of the measured air humidity. The operating mode of this embodiment is shown in Figure 3. If the air humidity is low, the fan 9 runs at maximum speed in an activation phase of the evaporator 4 and the time profiles of activation and de-activation phases, evaporator temperature and air humidity are the same as in the case in Figure 2. Consequently, the diagram in Figure 3 does not differ from that in Figure 2 as far as the time t_4. At time t_4, with reference to the high air humidity measured at this time the control circuit 10 selects a speed of the fan 9 which is lower than its maximum speed. During operation of the compressor and the fan, the air humidity decreases continuously and accordingly, the speed of the fan 9 selected by the control circuit 10 with reference to the measured air humidity increases and as circulation power of the fan 9 increases, the temperature of the evaporator 5 also

increases continuously over a large part of the time interval t_4 to t_5.

Figures 2 and 3 show the case of rapid drying when a single activation phase t_4 to t_5 is sufficient to return the air humidity in the cooling compartment to a target value. Naturally, the drying process can also be distributed over a plurality of successive activation phases.

In Figures 2 and 3 it was assumed that respectively the maximum circulation power of the fan 9 corresponds to a desired low air humidity value in the cooling compartment so that intensified drying can be achieved by throttling the circulation power. However, it is quite expedient to dimension the fan 9 so that a desired air humidity can already be achieved at an average circulation power. This allows the heat exchange between cooling compartment 1 and evaporator 5 to be intensified by increasing the circulation power above this average power so that the duration of an activation phase of the compressor 3 is shortened and in this activation phase, as a result of a relatively high temperature of the evaporator 5 its drying effect is weakened. It is thereby also possible to specifically increase the air humidity in the cooling compartment 1 when this falls below a desired value.